

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number:

0 067 446
A2

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 82105234.7

(51) Int. Cl.³: **G 05 B 19/417**
G 05 B 19/405

(22) Date of filing: 15.06.82

(30) Priority: 17.06.81 JP 92287/81

(43) Date of publication of application:
22.12.82 Bulletin 82/51

(84) Designated Contracting States:
DE FR

(71) Applicant: Hitachi, Ltd.
5-1, Marunouchi 1-chome
Chiyoda-ku Tokyo 100(JP)

(72) Inventor: Takeda, Kenji
4-27, Sasuke-1-chome
Kamakura-shi(JP)

(72) Inventor: Arai, Yoshinao
1-1-2-302, Katsuracho Totsuka-ku
Yokohama(JP)

(74) Representative: Patentanwälte Beetz sen. - Beetz jun.
Timpe - Siegfried - Schmitt-Fumian
Steinsdorfstrasse 10
D-8000 München 22(DE)

(54) Robot control data processing apparatus.

(57) A robot control data processing apparatus comprises a robot control data dividing processor (24) for dividing a robot control data (40 - 46) adapted for monitoring and controlling robots into a plurality of operation elements (50, 60, 70; 56, 66, 76; 57, 67, 77) and storing the robot control data in unit of the operation element, and a robot control data editing processor (26) for selectively combining and editing one or more of the plurality of the divisional operation elements (50, 60, 70; 56, 66, 76; 57, 67, 77). The robot control data is prepared by teaching the robots in operation and/or programming a robot oriented language.

EP 0 067 446 A2

./...

FIG. 2

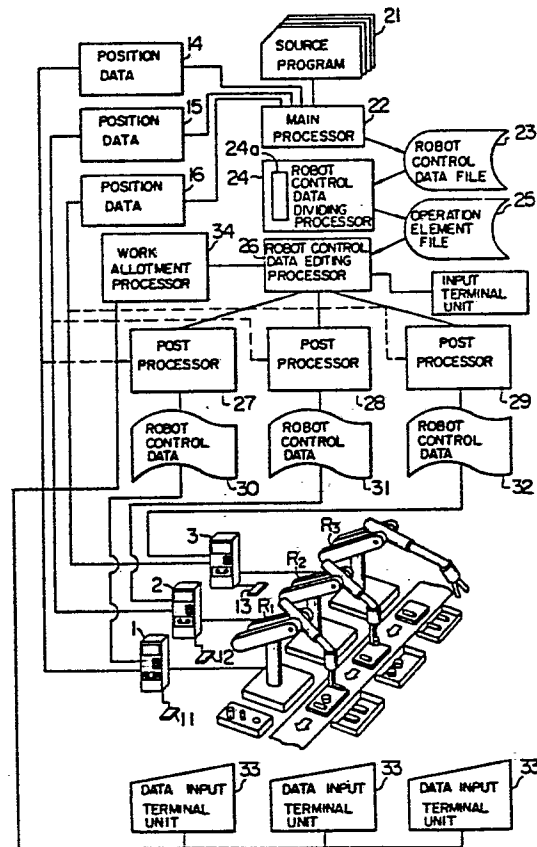
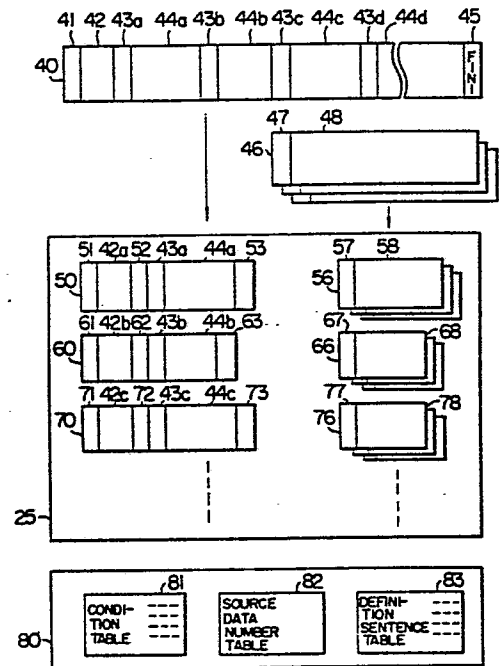


FIG. 3



- 1 -

ROBOT CONTROL DATA PROCESSING APPARATUS

1 This invention relates to a robot control
data processing apparatus which can prepare updated
robot control data conformable to changes of work field
situation on the basis of robot control data for
5 controlling motion of robots.

 In recent years, a great number of robots have
been introduced into factories for automation therein.
The robots contribute to improved productivity since
they can perform more varieties of working than conven-
10 tional uni-functional automated equipments by simply
changing robot control data. Fig. 1 is a perspective
view illustrating a work field to which such robots are
applied. For example, there are provided in the work
field three robots R_1 to R_3 , robot controllers 1 to 3
15 for controlling the respective robots, a conveyor 4,
and parts supply stations 5 to 7.

 The robot control data is prepared by making
assumptive correspondence between each of the robots
and sequence of workings pursuant to scheduled workings
20 to be performed by each of the robots. The individual
robots R_1 to R_3 have ability to perform various kinds
of workings and hence there are some alterable schedules
for a robot used for assembling a product and sequence
of workings for the used robot. Considering changes of
25 work field situation, such as alternation of the type

1 of products (product mix), occurrence of products on
urgent order and failure of robots, which leads to under
or over work to be performed by the individual robots,
it is desirable that work allotment to the individual
5 robots be changed for highly efficient utilization of
the work field. However, as far as a conventional robot
control data preparation method is concerned, teaching
or programming for robot control data needs to be
renewed when the number of robots is increased for
10 increasing production output or the aforementioned
changes of work field situation occur so that work
allotment to the individual robots is necessarily
changed. This renewal is time-consuming and trouble-
some, resulting in failure to make quick response to
15 the changes of work field situation.

The present invention contemplates elimination
of the conventional disadvantages and has for its object
to provide a robot control data processing apparatus
capable of effecting work allotment to robots in unit
20 of operation element and instantaneously editing neces-
sary robot control data to thereby follow changes of
work field situation.

According to this invention, the robot control
data processing apparatus comprises a robot control
25 data dividing processor for dividing robot control data
into units of operation element, and a robot control
data editing processor for combining and editing the
operation elements in accordance with current work

1 field situation. Advantagenously, robot control data
can be prepared in such a manner that sequence of
workings to be shared by robots for assembling a
product is not fixedly scheduled for the individual
5 robots, thereby making it possible to instantaneously
make work allotment conformable to changes of work
field situation and supply updated necessary robot
control data with attainment of improved rate of robot
operation and improved productivity.

10 The present invention will be apparent from
the following detailed description taken in conjunction
with the accompanying drawings, in which:

Fig. 1 is a perspective view of an assembling
line utilizing robots;

15 Fig. 2 is a block diagram of an automated
assembling line to which a robot control data processing
apparatus of this invention is applied;

Fig. 3 illustrates data formats useful in
explaining the operation of a robot control data divid-
20 ing processor used in the apparatus of Fig. 2;

Fig. 4 is a flow chart for explaining the
operation of the robot control data dividing processor;

Fig. 5 illustrates one example of operational
precedence relation;

25 Figs. 6A, 6B, and 6C illustrate various
results of work allotment;

Fig. 7 illustrates data formats useful in
explaining the operation of a robot control data editing

1 processor used in the apparatus of Fig. 2;

Figs. 8 and 9 are flow charts for explaining the operation of the data editing processor;

Fig. 10 is a block diagram showing a robot
5 controller and a teaching box in accordance with the invention;

Fig. 11 is a plan view showing an external appearance of the teaching box;

Fig. 12 schematically illustrates, in an
10 articulatory form, a robot;

Fig. 13 illustrates an example of dividing a program of operation sequence in robot language and start condition data and end condition data thereof;

Fig. 14 illustrates an example of wrong
15 editing without considering start condition and end condition independent of this invention; and

Fig. 15 illustrates the editing results in view of start condition and end condition according to this invention.

20 Prior to describing a robot control data processing apparatus embodying the invention, robot control data formulation and terminologies appearing in this specification will first be explained.

Typically, the data for controlling a robot
25 consists of "operation sequence data" which instructs sequence of operations of the robot and "position data" which instructs positions at which the operations are performed. The operation sequence data is a series of

- 5 -

1 instructions for instructing, for example, exchange of
finger tools, movement to a position and release of
finger tools. The position data is numerical data
representative of positions at which the operations are
5 performed.

The operation sequence data and position data
are described in combination in one robot control data
or alternatively, they are described in independent
forms and reference is made to the position data during
10 execution of the operations. Of available methods for
data preparation, a first method is such that the
operation sequence data and position data are both
inputted from source program, a second method is such
that only the operation sequence data is inputted from
15 the source program whereas the position data is directly
fetched at a position at which the robot is operating,
and a third method is such that the operation sequence
data and position data are inputted by manipulating
push buttons on a teaching box attached to the robot.

20 In the following description, the robot
control data preparation is based on the second method
wherein the operation sequence data is inputted from
the source program and the position data is directly
fetched by operating robots through the use of teaching
25 boxes associated therewith at positions at which the
robots are operating. Also, the operation sequence data
and position data are described in independent forms.
However, the invention may be implemented based on the

1 other methods for data preparation.

Now, definitions of terminologies appearing in the present specification will be explained.

(1) Operation element

5 A minimum work unit to be allotted to a robot. When assembling a product, a single type of finger tool works over a range defined by an operation element to assemble identical parts.

Operation sequence data corresponding to the
10 operation element is called operation sequence element data. Position data corresponding to the operation element is called position element data.

(2) Work precedence relation

When there is an operation element to be
15 executed prior to execution of another operation element, relation between the former (preceding operation element) and the latter (following operation element) is defined as work precedence relation. In wheel assembling work for automobiles, for example, mounting
20 of a wheel to a wheel base stands for a preceding operation element relative to bolt tightening work.

(3) Work group

A set of sequential operation elements including workings to be shared by a single robot in
25 accordance with loading, planning and rate of operation.

(4) Record

Robot control data, and information regarding finger operations and information for instructing

1 various functions of a robot which are temporarily stored
in a memory for preparation of the robot control data.
A record is classified into the following definition
sentence, operation data and condition data.

5 (5) Definition sentence

This defines the name of source program, used
robot number and used finger tool number.

(6) Operation data

This data instructs an actual operation of a
10 robot finger and contains data regarding movement
direction, speed and stoppage of the finger.

(7) Condition data

This data instructs the operation conditions
of the robot, such as operating speed, compensating
15 system of operating track, operating order of each
shaft and synchronism with other peripheral equipments
such as parts supplier and conveyor.

Referring now to Figs. 2 to 12, a preferred
embodiment of the invention will be described.

20 Fig. 2 shows an overall construction of an
assembling line comprised of robots R_1 to R_3 to which
the present invention is applied. A source program 21
based on a robot oriented language prepared without
assumptive workings for the individual robots is
25 processed by a main processor 22 of an automatic
programming device and stored, as operation sequence
data representative of a series of workings of all the
robots necessary for assembling a product, in a robot

1 control data file 23.

For example, the robot languages are as follows:

PROGRAM: instructs the program number of operation
sequence.

5 FINISH: instructs the end of program.

STOP: instructs the end of operation.

TOOL: instructs finger tool number which is used.

SPEED: instructs the operation speed.

10 MOVE: instructs the movement to the specified
position.

OPEN: opens tool.

CLOSE: closes tool.

POINT: instructs the position data number corresponding to the position data of moved position.

15 WAIT: instructs the stop of instructed hour and
operation.

AUX-ON: turns on the synchronizing output to
auxiliary machine.

20 AUX-OFF: turns off the synchronizing output to
auxiliary machine.

Furthermore, position data 14, 15 and 16
taught by teaching boxes 11, 12 and 13 associated with
the robots R_1 , R_2 and R_3 are also stored in the robot
control data file 23.

25 Incidentally, each of the robot controllers
1, 2 and 3 and each of the teaching boxes 11, 12 and 13
which are associated with the robots R_1 , R_2 and R_3 as
shown in Fig. 2 are detailed in Fig. 10. The teaching

1 boxes 11, 12 and 13 have each an external appearance as
shown in Fig. 11. When operation keys on the teaching
box 11, 12 or 13 are depressed, a data is fetched by
a microprocessor (A) 104 of the controller 1, 2 or 3
5 through a serial I/F 108 and a target coordinate value
in accordance with the key input data is calculated.
The controller 1, 2 or 3 and robot mechanism section
 R_1 , R_2 or R_3 constitute a position control system where-
in output values of pulse encoders PE are feedback via
10 a counter 107, and a difference between a previous
target coordinate value calculated by the microprocessor
(A) 104 that is in terms of an encoder converted value
and the feedback value is processed by a D/A 106 into
analog conversion outputs which drive actuators M.
15 Each of the robots R_1 , R_2 and R_3 has six degrees of
freedom and there are provided six actuators M, six
tacho-generators TG and six encoders.

Fig. 11 illustrates, in plan view, details
of the teaching box 11, 12 or 13. The teaching box
20 has a teaching work basic function operation panel which
is manipulated for ordinary manual movement of a robot
and storage of position data in the memory.

With reference to Fig. 12, posture information
of a robot is a Cartesian coordinate value which is
25 represented by six data in terms of mm unit and degree
unit corresponding to coordinates X, Y and Z of a finger
position P of the robot in XYZ coordinates and torsion
angles α , β and γ of the finger, where

- 10 -

- 1 α : angle made by a finger coordinate axis X_H with
 respect to XY plane,
 β : angle made by a finger coordinate axis Y_H with
 respect to XY plane, and
5 γ : absolute rotation angle of a finger shaft
 (#6).

 When a teaching program (stored in a ROM (23))
 for the microprocessor (A) 104 is started, key input
 commands from the teaching box is interpreted following
10 initialization of each data. To this end, keys on a
 teaching basic operation panel 119 of the teaching box
 11, 12 or 13 which are being depressed are addressed
 periodically by a microprocessor (B) 112 through a key
 board display I/F 113 in response to a signal from a
15 clock generator 114, addressed code data is sent to
 the microprocessor (A) 104 through bus line 118, ACIA
 116, level changer 115, serial I/F 108 and bus line 105
 in response to a data transfer requesting signal from
 the controller 1, 2 or 3, and the microprocessor (A)
20 104 analyzes the code data to determine what processing
 is instructed by the code data, so that the code data
 is transferred to a corresponding process routine and
 the program jumps to the process routine.

 Involved in this procedure are a teaching
25 processing (120a) for fetching the position coordinate
 value of robot into a memory 122, a mode change
 processing (120e, 120f) for selecting either an articu-
 latory mode wherein individual shafts are independently

1 moved during manual movement of the robot or an
orthogonal mode wherein fingers are moved along the
Cartesian coordinates, a hand lock and release process-
ing (120c, 120d), and a processing wherein the micro-
5 processor (B) 112 turns on LEDs (light emitting diodes)
121a to 121f located above depressed keys 120a to 120f
through the PIO 117 so as to indicate that the process-
ing keys 120a to 120f are depressed. These processings,
however, will not be detailed herein.

10 An arm operation processing (120g to 120r)
is adapted for calculating target values in accordance
with operation modes determined by the mode change
processing. The target values are determined in terms
of orthogonal coordinates (A) and stored in the RAM 122.
15 The determined target values correspond to a gradually
increasing displacement within a range not exceeding
a maximum displacement before initial depression of
the key for the target coordinates is released, and a
gradually decreasing displacement toward zero displace-
20 ment after the key is released, these target values
being added to or subtracted from coordinates (A)
determined in one preceding cycle in accordance with
the direction of movement to obtain current target
coordinates. The current target coordinates are
25 converted into corresponding encoder values for the
respective robot shafts. Actual current values are
obtained by reading outputs of the pulse encoders PE
through the counter 107. Thus, a difference between

1 the corresponding encoder value and the actual current
value is applied, in the form of a current command
pulse number, to the respective shafts through the D/A
106, thereby applying speed instructions to the servo-
5 driver and then driving the robot.

In this manner, position data in each operation element for each robot R_1 , R_2 or R_3 stored in the RAM 122 is read out through a communication interface 124 and then stored in the robot control data file 23.

10 Alternatively, position data may be stored in post processor 27, 28 or 29, only position data number may be divided and edited, and position data corresponding to the position data number may be inputted by the post processor 27, 28 or 29.

15 Returning to Fig. 2, a robot control data dividing processor 24 featuring the present invention divides robot control data for each finger tool and for each assembling parts and stores the same in an operation element file 25. On the other hand, a work allotment processor 34 fetches work field situation through
20 a sensor or data input terminal unit 33 to determine work allotment correspondingly, and instructs a robot control data editing processor 26 of the work allotment. The robot control data editing processor 26 featuring
25 the present invention combines and edits operation element for each robot in accordance with the work allotment instruction. The edited operation element is processed by the post processors 27 to 29 respectively

- 13 -

1 associated with the robots in view of data formats
specified thereto, thus preparing robot control data 30
to 32 for the respective robots.

The robot control data dividing processor 24
5 performs a processing as shown in Fig. 3. An operation
sequence data 40 corresponding to a product and repre-
senting an operation sequence of a robot necessary for
assembling the product includes an operation sequence
data number 41 corresponding to the product, a defini-
10 tion statement (representative of a hand and a finger
tool used) 42, finger tool designating data 43a, 43b,
43c, 43d ----- for designating a plurality of finger
tools generally used for assembling the single product,
operation data 44a, 44b, 44c, 44d ----- indicative of
15 operations by the designated finger tools and condition
therefor, the finger tool designating data and the
operation data constituting alternate sets of data,
and a code FINI 45 indicative of the end of data. A
product corresponding position data 46 representative
20 of positions of the robots R_1 , R_2 and R_3 at which the
operations are performed includes a position number
data number 47 and a position data 48 which are related
to position names in the operation sentence. As
described above, since the robots R_1 , R_2 and R_3 cannot
25 be positioned to an identical position even if an
identical position instruction is applied to the robots
 R_1 , R_2 and R_3 , the position data 46 is obtained by
operating and teaching the robots R_1 , R_2 and R_3 .

1 The robot control data dividing processor 24
divides the product corresponding data 40 and 46 into
one operation element data within a range of data
necessary for assembling one type of parts by the use of
5 a single finger tool, and stores, as the operation
element file 25, the operation element data in a memory
24a such as, for example, a magnetic disc or a magnetic
drum. Illustrated in the lower left of Fig. 3 are
operation sequence element data 50, 60 and 70. Each of
10 the operation sequence element data 50, 60 and 70
includes an operation sequence element number, a defini-
tion sentence, a start condition data, a finger tool
designating data, an operation data and an end condition
data. Each of the robots R_1 , R_2 , R_3 is provided with
15 the position data 56, 66 and 67 and the position element
data 56, 66 and 76 have position element numbers 57,
67 and 77 and position data 58, 68 and 78, respectively.
A memory region 80 as shown in Fig. 3 has a condition
table 81, a source data number table 82, and a definition
20 sentence table 83. This memory region may be part of
the memory for storage of the operation element file 25
or may be part of the memory 24a built in the robot
control data dividing processor 24.

Referring now to Fig. 4, the manner of
25 dividing all the control data 40 and 46 to prepare the
operation element data 50, 60 70 ----- and position
element data 56, 66, 76 ----- will be described.

When reading out all the data 41 to 45 in the

- 15 -

1 operation sequence data 40, all the table 81 to 83 in
the memory region 80 are first cleared in step 90. The
operation sequence data 40 is read out one by one record
and it is judged in steps 91 and 92 as to what data the
5 one record is. In accordance with the results of the
judgment, the one record data proceeds to either step
93, 94, 95, 96, 97, 98 or 100.

Firstly, the operation sequence data number
41, specifically, "D0001", for example, is read out and
10 stored in the table 82 of the storage region 80 in step
93. Subsequently, the definition sentence 42 is stored
in the table 83 of the storage region 80 in step 94.

Next, the finger tool designating data 43a is
examined in step 95 for its inputting frequency. At
15 present, the inputted finger tool designating data 43a
of the first occurrence is sent to step 96, in which
the following processings are preformed. Firstly, the
operation sequence data number 41 i.e., "D0001" stored
in the table 82 is added with a serial number to
20 prepare the operation sequence element number 51, for
example, "D0001-1". This operation sequence element
number 51 is stored in the first stage of the operation
element file 25. Secondly, the definition sentence 42
stored in the table 83 is stored, as definition statement
25 42a, in the file 25 to follow the operation element
number 51. Thirdly, the condition data in the table 81
is stored, as start condition data 52, in the file 25
to follow the definition statement 42a. Fourthly, the

- 16 -

1 finger tool designating data 43a now inputted is stored
in the file 25 to follow the start condition data 52.

Subsequently, the operation data 44a including,
as described previously, a plurality of records consist-
5 ing of a pure operation data for the robot hand and a
condition data for designating conditions for work is
judged one by one record in step 92 and sent to step 97
or 98. The robot hand operation data is prepared in
step 97 and stored in the file 25 to follow the finger
10 tool designating data 43a. This operation data is
referenced to the position data, and if referenced
initially in the position data corresponding operation
element with respect to each of the robots R_1 , R_2 , R_3 ,
it is made correspondent to the operation element for
15 storage in the file 25. On the other hand, the condi-
tion data is prepared in step 98 and stored in the
file 25 to follow the operation data 44a. This condition
data updates the contents of the condition table 81 of
the storage region 80. More specifically, the operation
20 data 44a in the operation sequence data 40 is trans-
ferred, as it is, to the operation sequence element
data 50 to follow the finger tool designating data 43a,
and each time the condition data in the operation data
44a is extracted, the contents of the table 81 are
25 updated.

Next, the finger tool designating data 43b
is inputted to step 95 via steps 91 and 92. This data
43b of the second occurrence is then sent to step 99,

- 17 -

1 in which the following processings are performed. The
data of the condition table 81 updated in the previous
processing is formed into the end condition data in the
first operation sequence element and added, as end
5 condition data 53, to the end of the operation sequence
element data 50. In this manner, preparation of the
first operation sequence element data 50 has been
completed.

The completion of preparation of the first
10 operation sequence element data 50 implies start of
preparing the second operation sequence element data
60, and the step 96 is executed following step 99. In
the step 96, like the preparation of the first operation
sequence element data 50, the operation sequence element
15 number 61 ("D0001-2"), definition statement 42b, start
condition data 62 and finger tool designating data 43b
are prepared and stored in the second stage of the
operation element file 25 in the order of data 61, 42b,
62 and 43b. Of course, the start condition data 62
20 standing for the data of the table 81 and the finger
tool designating data 43b of the second occurrence are
now put in storage. Following the preparation of the
second operation sequence element data 60 (61, 42b, 62,
43b and 63), the third operation sequence element data
25 70 (71, 42c, 72, 43c and 73) and so on are prepared in
a similar manner.

Finally, the FINISH code 45 is read and the
end of the last stage operation sequence element data

1 is added with the data of the condition table 81 as
end condition data, thus completing the division of the
operation sequence data 40. In the above division
processing, the position data 46 is divided into 56,
5 66 and 76 which correspond to position values used for
the respective operation elements, and these divisional
data are prepared.

The robot control data is edited in accordance with a work allotment instruction from the work
10 allotment processor 34. The work allotment is performed
by making reference to conditions of the work precedence
relation between the operation elements on the basis of
information from the sensor or data input terminal unit
33, namely, work loading condition of each of the robots
15 R_1 , R_2 and R_3 , presence or absence of failure of machine
and finger tool mounting condition. In controlling a
plurality of robots each having a plurality of finger
tools, the most efficient work allotment to the individual
robots may be searched for by, for example, a
20 wellknown branch boundary method (B.B.M) or dynamic
planning (D.P) which treats problems on assembling line
balance.

For example, it is now assumed that one
product assembling is composed of six operation elements,
25 work capability of the individual robots is as shown in
Table 1, and the work precedence relation between the
operation elements is as shown in Fig. 5.

Table 1

Operation element number	Finger tool number	R_1	R_2	R_3	Work time (sec)
D0001-1	T182	o	o	x	8
D0001-2	T114	x	o	o	4
D0001-3	T093	o	x	x	8
D0001-4	T080	o	x	o	4
D0001-5	T521	x	o	o	6
D0001-6	T201	x	o	o	6

1 In Table 1, validity of working operation elements "D0001-1" to "D0001-6" by the robots R_1 , R_2 and R_3 is denoted by a mark "o" and invalidity is denoted by a mark "x". Validity or invalidity depends

5 on specification of each robot R_1 , R_2 or R_3 and which type of finger tool adapted for a specified operation element the robot R_1 , R_2 or R_3 carries, T182, T114, --- or T201. Itemized in the righthand-end column in Table 1 are work times for the operation element.

10 Work sequence among the operation elements "D0001-1" to "D0001-6" necessary for assembling one product is technically constrained to follow the work precedence relation as shown in Fig. 5. In a diagrammatic representation of Fig. 5, arrows imply the

15 constrained work sequence according to which the operation element "D0001-4", for example, cannot start working before workings of the operation elements

1 "D0001-2" and "D0001-3" have been completed. Such
various types of information as depicted in Table 1 and
Fig. 5 have previously been inputted to the work
allotment processor 34 from the sensor or data input
5 terminal unit 33 and the work allotment processor 34
performs work allotment to the individual robots R_1 to
 R_3 on the basis of the wellknown search theory. It will
readily be appreciated that if in this example the
operation elements "D0001-1" and "D0001-2" are
10 shared by the robot R_2 , the operation elements
"D0001-3" and "D0001-4" are shared by the robot R_1
and the operation elements "D0001-5" and "D0001-6"
are shared by the robot R_3 , each of the robots R_1 , R_2
and R_3 will perform the most efficient work within a
15 work time of 12 seconds. This work allotment is
illustrated in Fig. 6A in which the robot symbols are
described in circles.

Assuming that the robot R_2 becomes out of
order, it is necessary to allot the work shared by the
20 robot R_2 to the robots R_1 and R_3 and rearrange work time
for the robots R_1 and R_3 . If marks "o" representative
of valid capability owned by the robot R_2 in Table 1 are
simply replaced by marks "x", the operation elements
now invalid for the robot R_2 but valid for the robot
25 R_1 or R_3 will automatically be determined and work
allotment to the robots R_1 and R_3 will be as shown in
Table 2.

Table 2

Robot	Operation element number	Work time (sec)
R_1	D0001-1, D0001-3	16
R_3	D0001-2, D0001-5, D0001-6	16

1 In this case, the work time for both the robots R_1 and R_3 is 16 seconds and the remaining operation element "D0001-4" may optionally be allotted to either the robot R_1 or the robot R_3 . In determining
5 the allotment of the operation element "D0001-4", the frequency of movements of the product through the robots and the direction of flow of the assembling line should be taken into consideration since these factors are dependent on sequence of processings.

10 The operation element "D0001-4" is allotted to the robot R_1 in Fig. 6B and to the robot R_3 in Fig. 6C. As will be seen from Figs. 6B and 6C, the allotment according to Fig. 6C is reduced in frequency of movements of the product through the robots and is
15 more advantageous than the allotment according to Fig. 6B.

 The robot control data is edited by the robot control data editing processor 24 in accordance with a work allotment instruction from the work allotment
20 processor 34. The editing process is exemplified in

1 Fig. 7 and the robot control data editing processor
26 performs this process in accordance with flow charts
as shown in Figs. 8 and 9.

Illustrated in the upper block are six operation
5 tion sequence element data 50, 60, 70, 110, 120 and 130
and corresponding position element data 56, 66, 76, 116,
126 and 136 which are provided in each of the robots
 R_1 , R_2 , R_3 , these data being obtained from the division
processing as shown in Fig. 3. The operation element
10 numbers correspond to those shown in Table 1. The
editing processing will be exemplified on the assumption
that the work allotment is pursuant to Fig. 6C in the
event of failure of the robot R_2 .

Operation sequence data for the robot R_1 is
15 edited by the operation sequence element data 50 and
70, and operation sequence data for the robot R_3 is
edited by the operation sequence element data 60, 110,
120 and 130. Similarly, position data for the robot R_1
is edited by making reference to the data 56 and 76,
20 and position data for the robot R_3 is edited by making
reference to the position data of the corresponding
robot of the data 66, 116, 126 and 136.

Firstly, when, in the event of failure of the
robot R_2 , failure information is fed from the sensor or
25 data input terminal unit 33 associated with the robot
 R_2 to the work allotment processor 34, this processor
34 performs the aforementioned work allotment and at
the same time, transmits results of the allotment and

1 an editing instruction to the robot control data
editing processor 26. In step 160, the robot control
data editing processor 26 reads the allotment results
and editing instruction. In step 161, predetermined
5 operation sequence element data (a work group 140
composed of data 50 and 70, and a work group 150
composed of data 60, 110, 120 and 130) is read out of
the operation element file 25 shown in Figs. 2 and 3
and arranged.

10 To describe the first work group 140, among
the operation sequence element data 50 and 70 arranged
in step 161, the start condition data 52 of the
operation sequence element data 50 is compared with the
end condition data of an operation sequence element
15 data preceding by one element in step 162. In this
example, since there is no data preceding the operation
sequence element data 50, the start condition data 52
as it is is set as initial state.

Subsequently, the start condition data 72 of
20 the operation sequence element data 70 is compared with
the end condition data 53 of the operation sequence
element data 50 which precedes by one element, and if
there is a different data, this different data is
inserted as condition change data 141 behind the start
25 condition data 72. If many operation elements are
present in one work group, a number of insertions of
the condition change data are carried out sequentially.

Thereafter, in step 163, the start condition

1 data 52 and 72, end condition data 53 and 73, source
data number 71 of the second and following occurrence,
and definition statement 42c are removed. In step 164,
the end of the data is added with a FINISH code 142,
5 thereby completing an operation sequence data 140 of
the first work group.

For preparation of the second work group, a
similar processing is performed wherein condition
change data 151 and 152 are newly inserted and a FINISH
10 code 153 is added to complete an operation sequence data
150 of the second work group.

For preparation of the position element data,
on the other hand, the allotment results and editing
instruction are read in step 170 and in step 171,
15 the position data of the corresponding robot is read out
in the order of read-in operation element numbers and
arranged in this order. Thereafter, if some of the
position data arranged have the same name, these data
are removed.

20 In this manner, the position data 146 of the
first work group and the position data 156 of the second
work group can be prepared.

Fig. 13 illustrates a program example of
operation sequence in a robot language and three portions
25 of D0001-4 (204), D0001-5 (205), and D0001-6 (206)
divided by the system of this invention. Now, as
considering the operation speed (SPEED) of the robot
and the on-off (AUX-ON, AUX-OFF) of the synchronized

1 output to the peripheral equipments of an apparatus
No. 120 as data condition, the start condition data of
each element work become 214, 215, and 216, and the end
condition data become 224, 225 and 226.

5 Then, some works are assigned to the robot
 R_3 in order to directly perform D0001-6 after D0001-4.

If D0001-4 and D0001-6 are combined without
considering the start condition and the end condition,
as shown in Fig. 14, there occurs the malfunction that
10 the first operation MOVE POINT 61 which should original-
ly operate at SPEED 10 moves at SPEED 20 which is the
speed condition of D0001-4.

According to this invention, the robot control
data processing apparatus can operate at SPEED 20 under
15 the right condition only by comparing the end condition
224 of D0001-4 with the start condition 216 of D0001-6
and by newly inserting the instruction languages SPEED
10 and AUX-ON 120 (230), and the apparatus No. 120 can
be started in the on-state of the synchronized output,
20 and consequently the operation sequence of the right
work group can be obtained immediately.

If original positions of the robots R_1 , R_2
and R_3 (at which the counter 107 is reset) and a
product reference point of the product to be assembled
25 are measured by a suitable instrument and these data
are inputted through an input terminal unit 35 and
stored, it is possible to change the position data so
as to be adapted for the robot. If amounts of

- 26 -

- 1 operations of the robots R_1 , R_2 and R_3 are different,
correction coefficients determined by teaching several
points within the operating area of the robot may be
inputted through the input terminal unit 35 and stored,
5 and the position data may be multiplied by the stored
correction coefficients, thus making it possible to
provide the position data in a similar form to the
source program 21 without teaching at all robots every
individual product.
- 10 The operation sequence data 40 may be divided
into the operation elements in various manners. For
example, one method is available wherein each of the
operation sequence element data is constituted by only
the finger tool designating data 43a, 43b, 43c -----
15 and operation data 44a, 44b, 44c -----, the source data
number and the definition statement are formed into
one operation element, the FINI statement deemed as one
operation element is stored in the operation element
file, and the start condition data 52, 62, 72, -----
20 and end condition data 53, 63, 73, ----- corresponding
to the respective operation elements are related to the
operation elements and stored in storage regions.
According to this method, editing can be performed
by repeating a procedure in which the operation element
25 composed of the source data number and definition
statement is read out, the end condition of this
operation element is compared with the start condition
of the initially designated operation element for

- 27 -

- 1 insertion of the condition change data, and thereafter the corresponding operation element data is supplied, thereby simplifying the division and editing work.

As has been described, according to the

- 5 present invention, the robot control data can be prepared freely by combining a plurality of operation elements which are prepared by dividing all the control data necessary for assembling a single product, so that the rate of operation of the robots and production
- 10 efficiency can be improved by making work allotment in unit of the operation element so as to follow transitional changes of work field situation.

WHAT IS CLAIMED IS:

1. A robot control data processing apparatus comprising:

a robot control data dividing processor (24)
5 for dividing a robot control data (40, 46; 47) adapted for monitoring and controlling robots into a plurality of operation elements (50, 60, 70; 56, 66, 76; 57, 67, 77) and storing the robot control data in unit of the operation element, said robot control data being pre-
10 pared by teaching the robots in operation and/or programming a robot language; and

a robot control data editing processor (26)
for selectively combining and editing one or more of the plurality of the divisional operation elements
15 (50, 60, 70; 56, 66, 76; 57, 67, 77).

2. A robot control data processing apparatus according to claim 1 further comprising a work allotment processor (34) for determining work allotment to each of the robots in accordance with work loading condition
20 of the plurality of robots, hand or finger tool mounting condition and work precedence relation of the robots between the operation elements.

3. A robot control data processing apparatus according to claim 1 wherein said robot control data
25 dividing processor (24) comprises storage means (24a) for storing data of each operation element, said storage means having storage regions (81, 82, 83) for storing at least a start condition data for starting operation

of each operation element, an end condition data issued at the time of ending the operation, and an operation data.

4. A robot control data processing apparatus
- 5 according to claim 3 wherein said end condition data of each operation element is updated by analyzing a condition data included in the operation data for each operation element when said robot control data dividing processor divides the robot control data.
- 10 5. A robot control data processing apparatus according to claim 4 wherein when combining and editing predetermined one of the operation element data prepared by division by said robot control data dividing processor, said robot control data editing processor compares
- 15 the start condition data of the predetermined operation data with the end condition data of a edited operation element data preceding by one element and inserts a condition data based on the difference.

FIG. 1 PRIOR ART

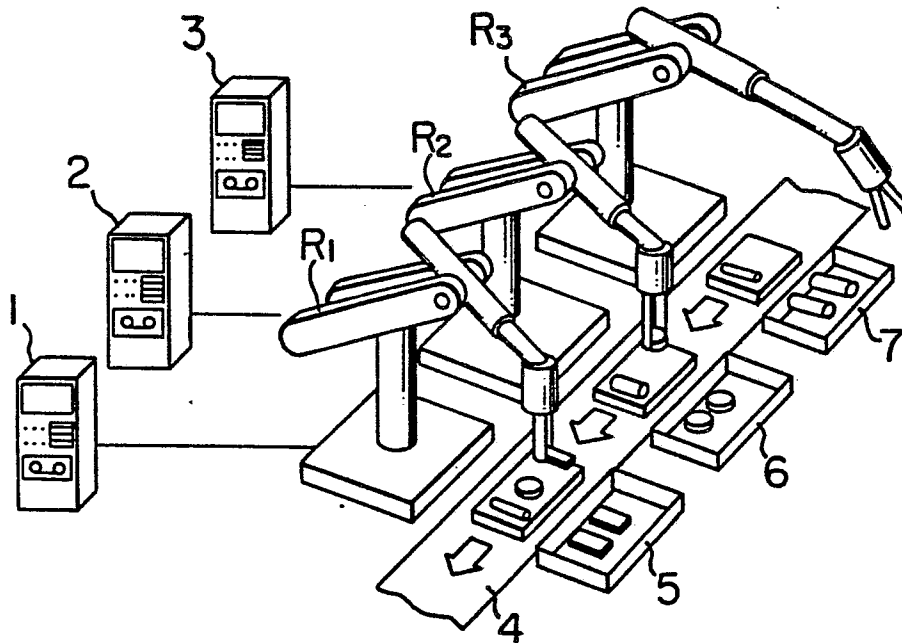


FIG. 5

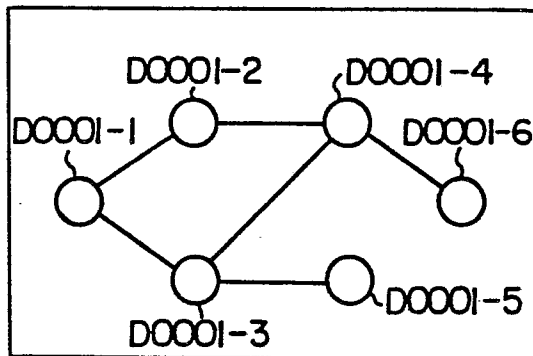


FIG. 6A

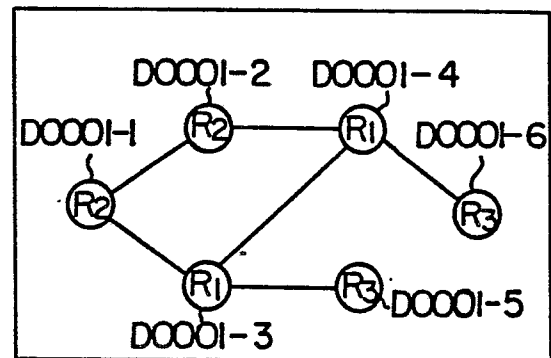


FIG. 6B

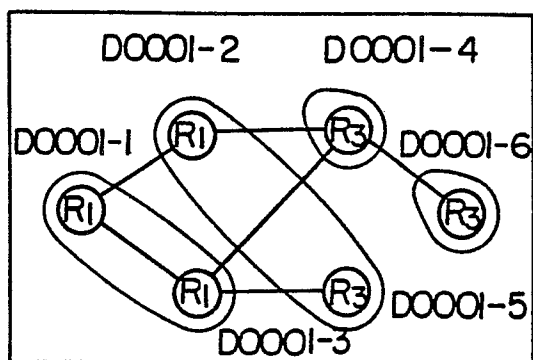
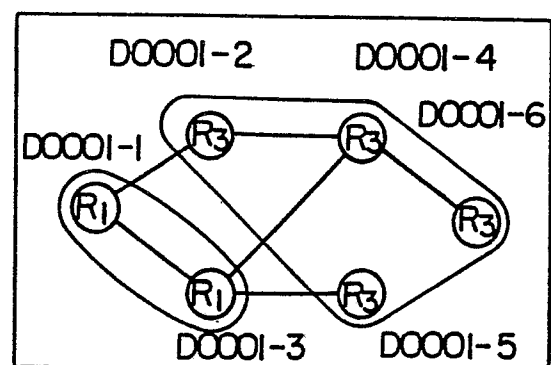
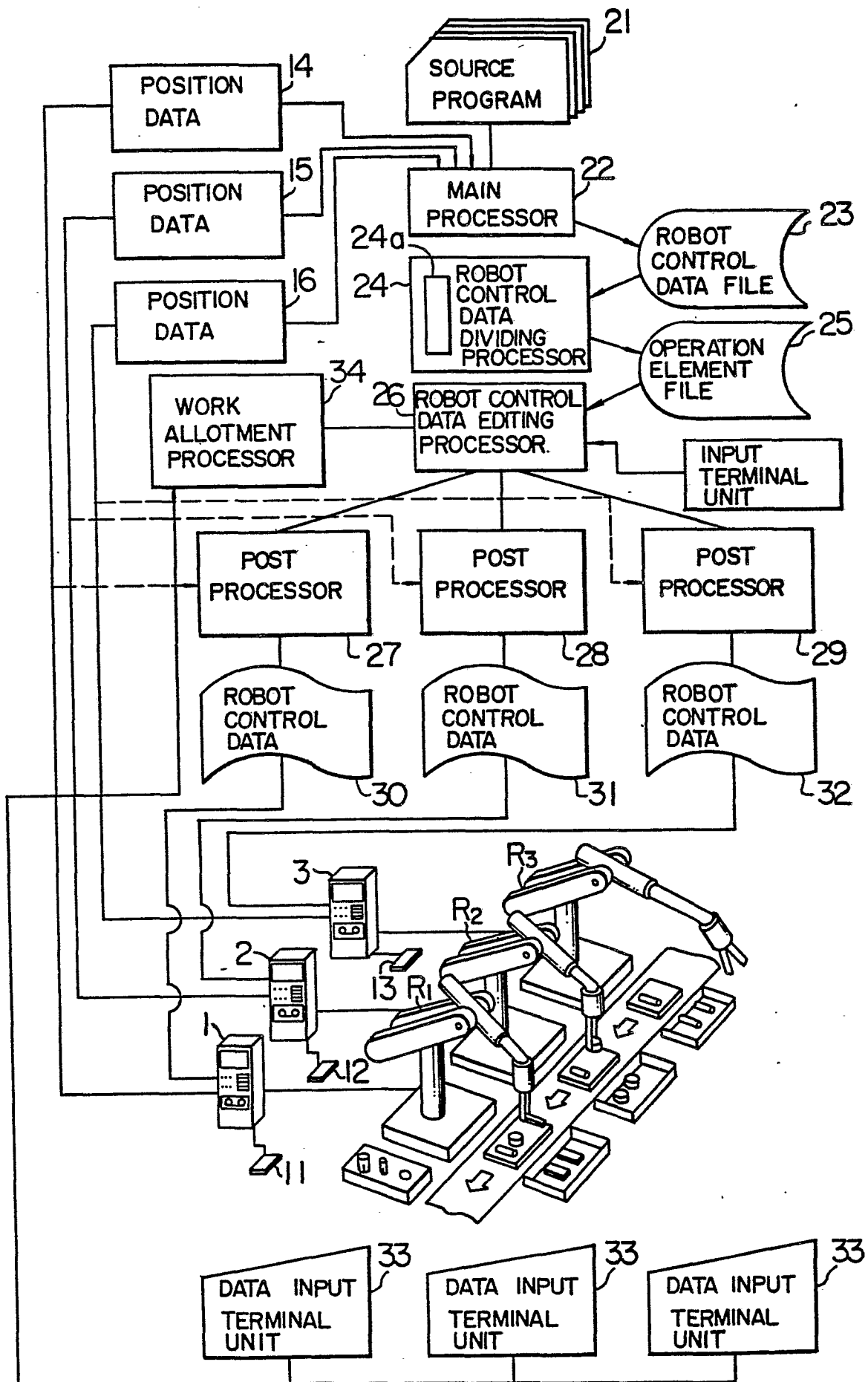


FIG. 6C



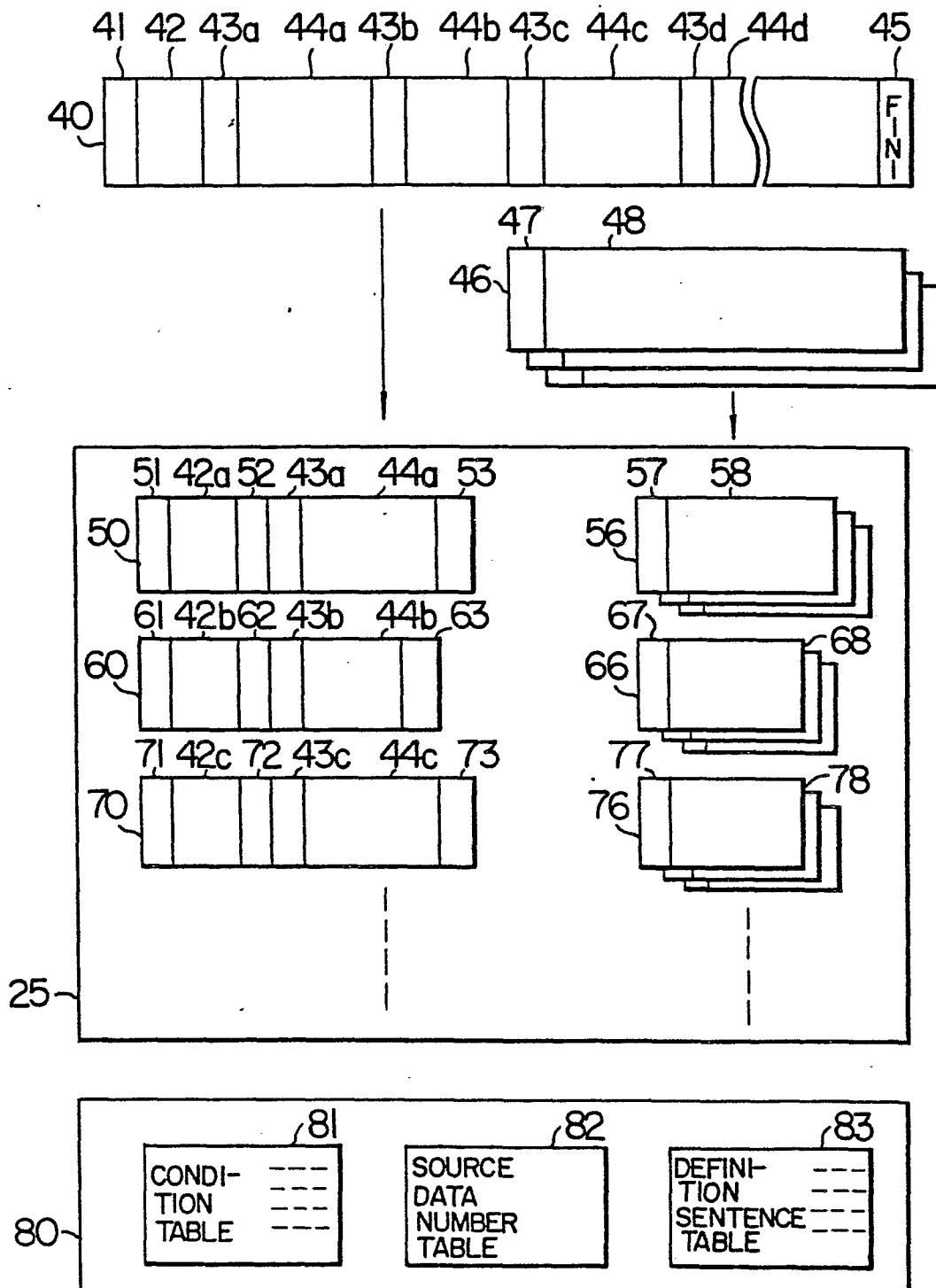
2/11

FIG. 2



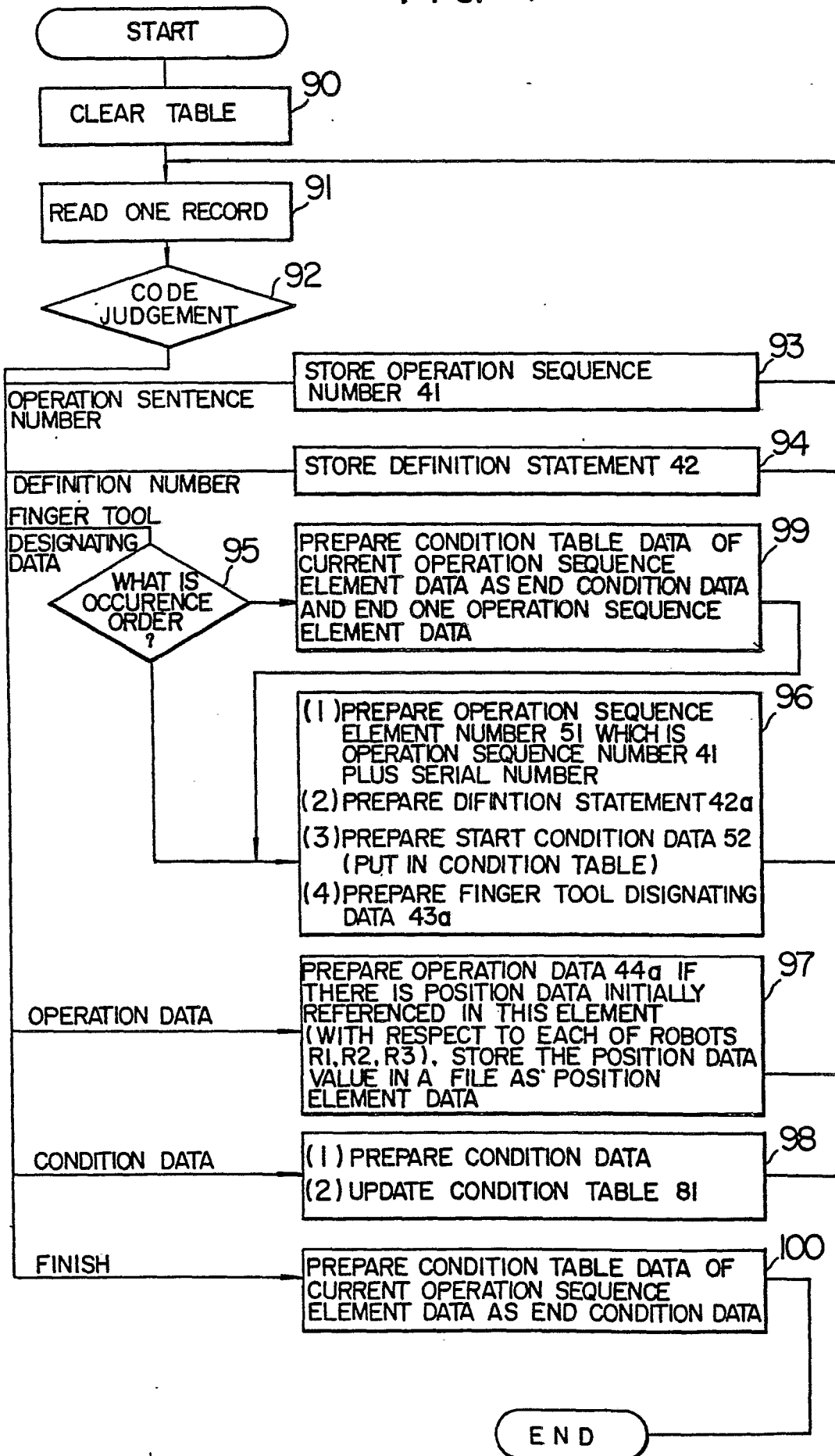
3/11

FIG. 3



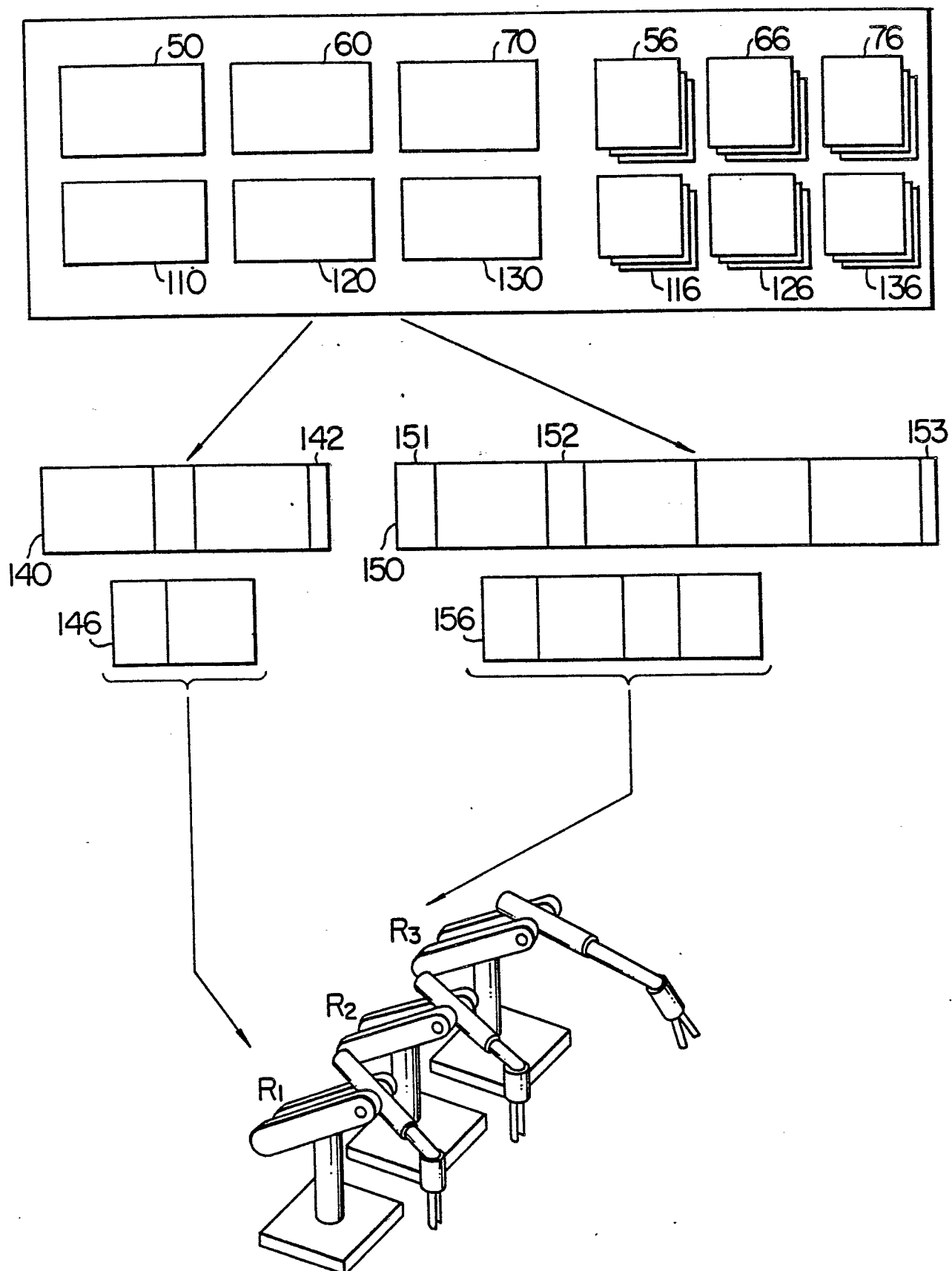
4/11

FIG. 4



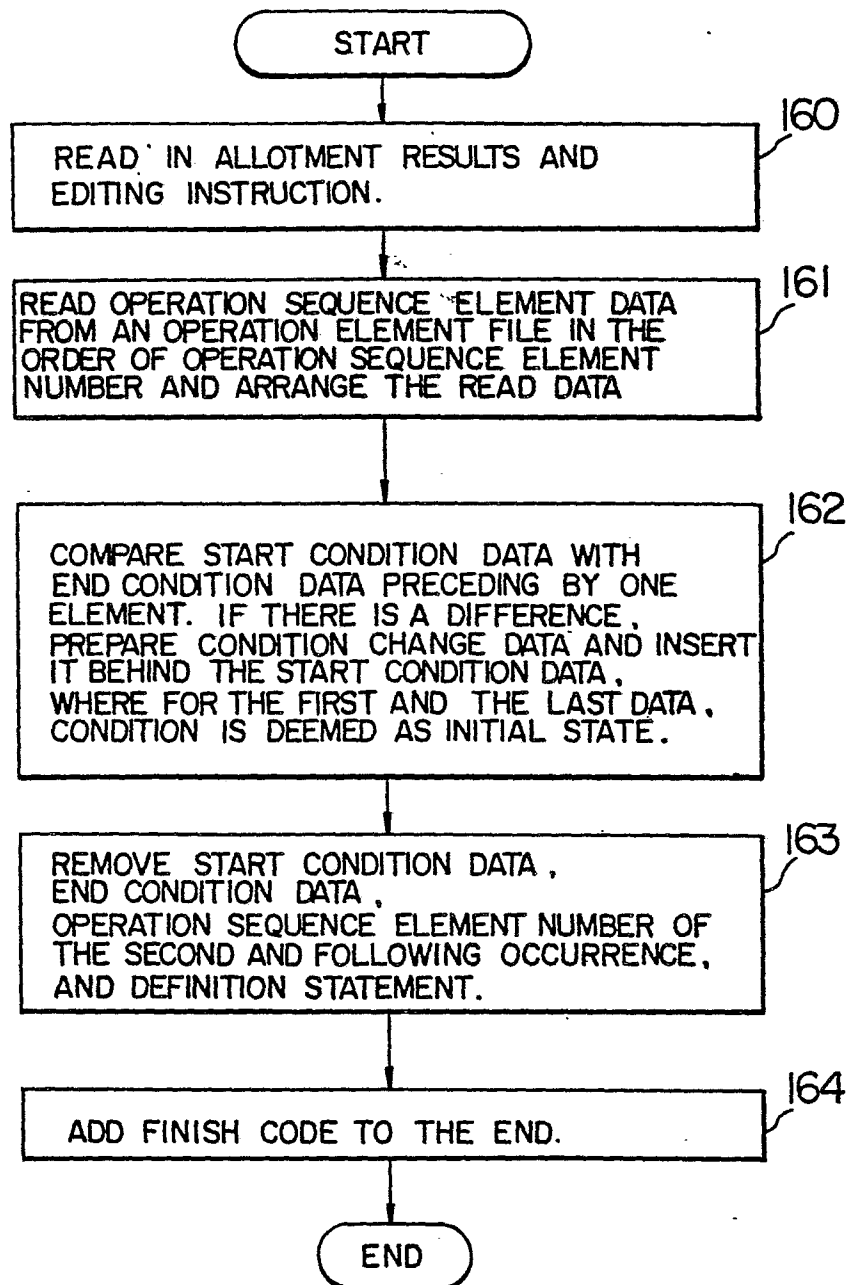
5/11

FIG. 7



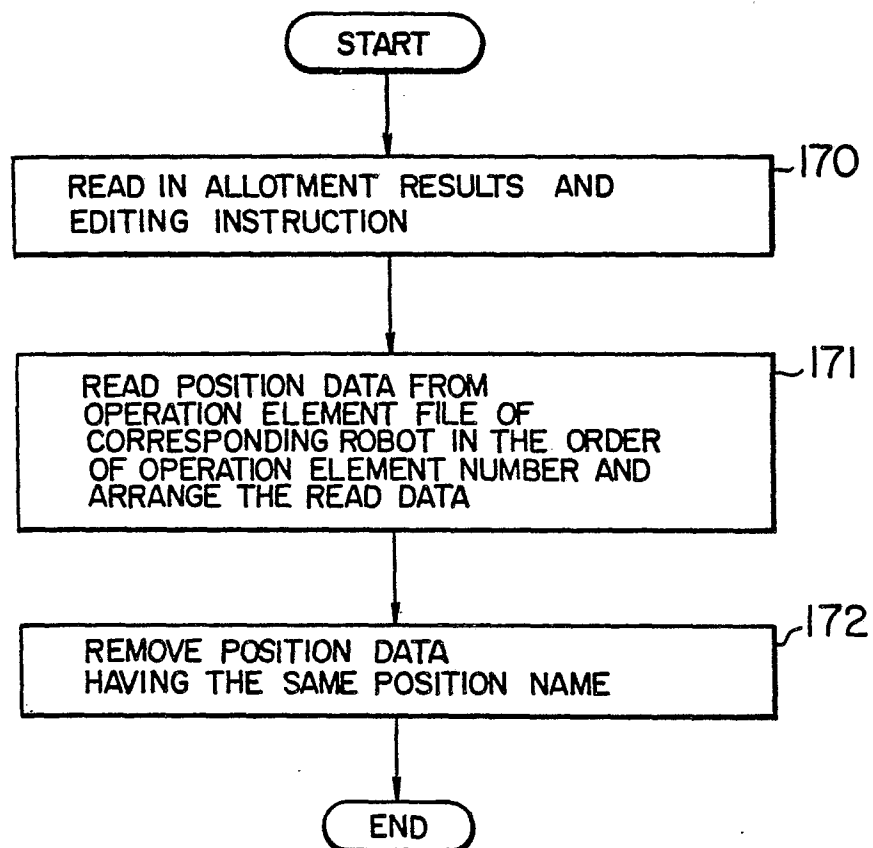
6/11

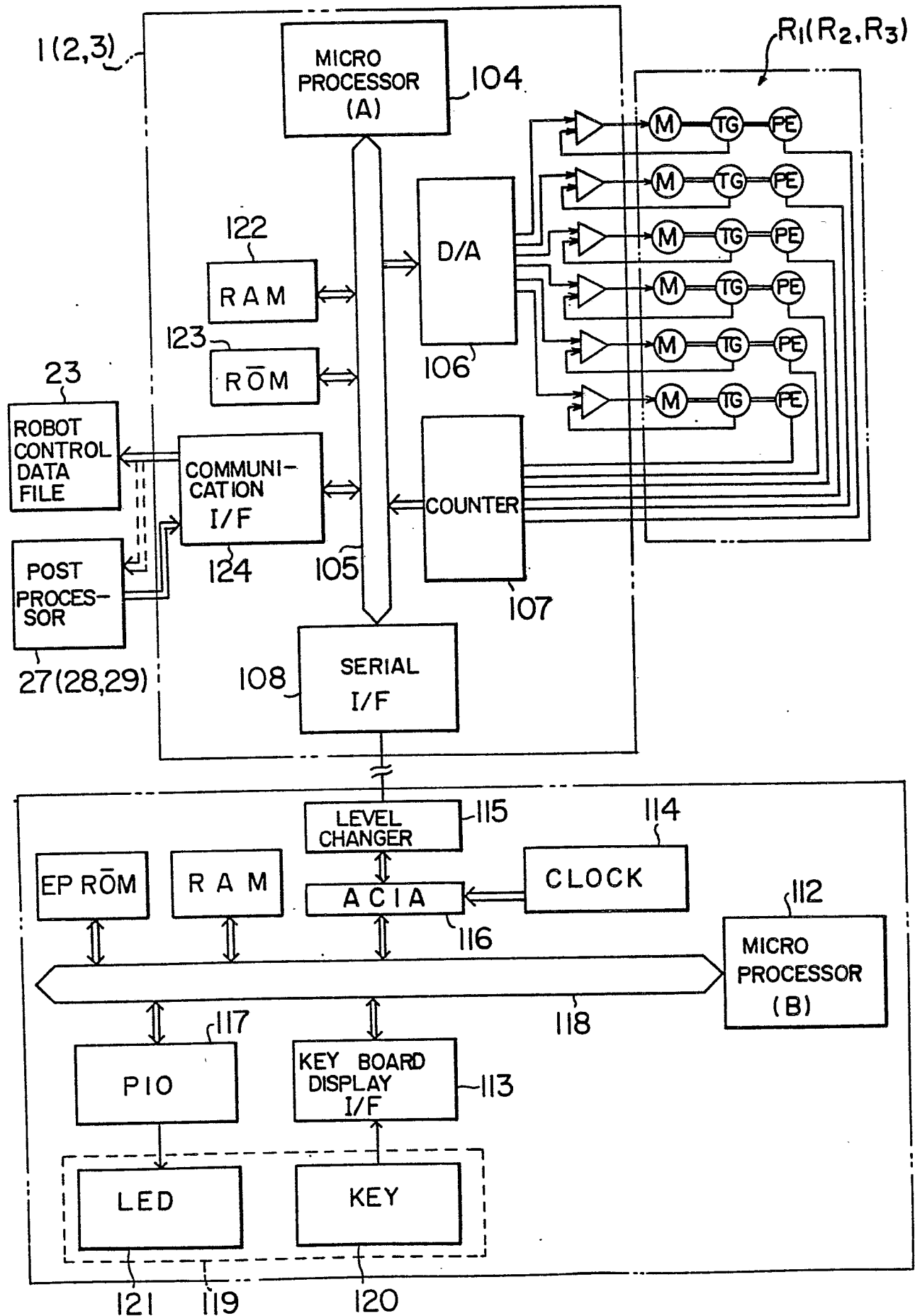
FIG. 8



7/11

FIG. 9



8/11
FIG. 10

9/11

FIG. 11

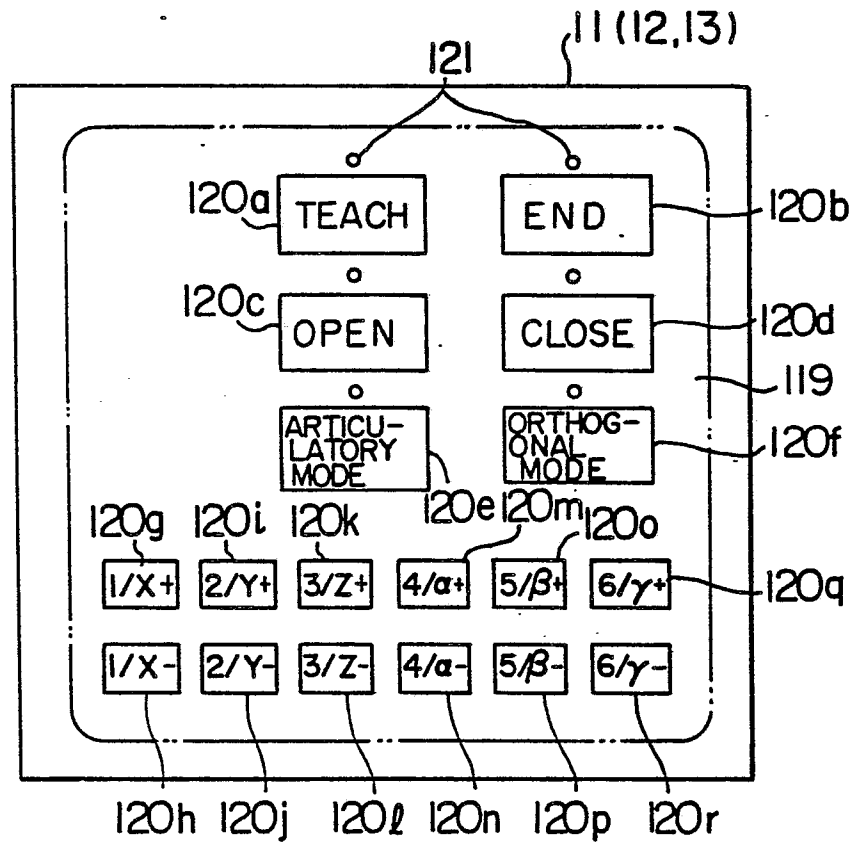
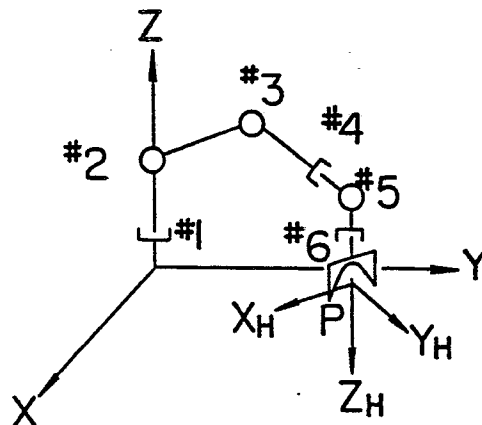
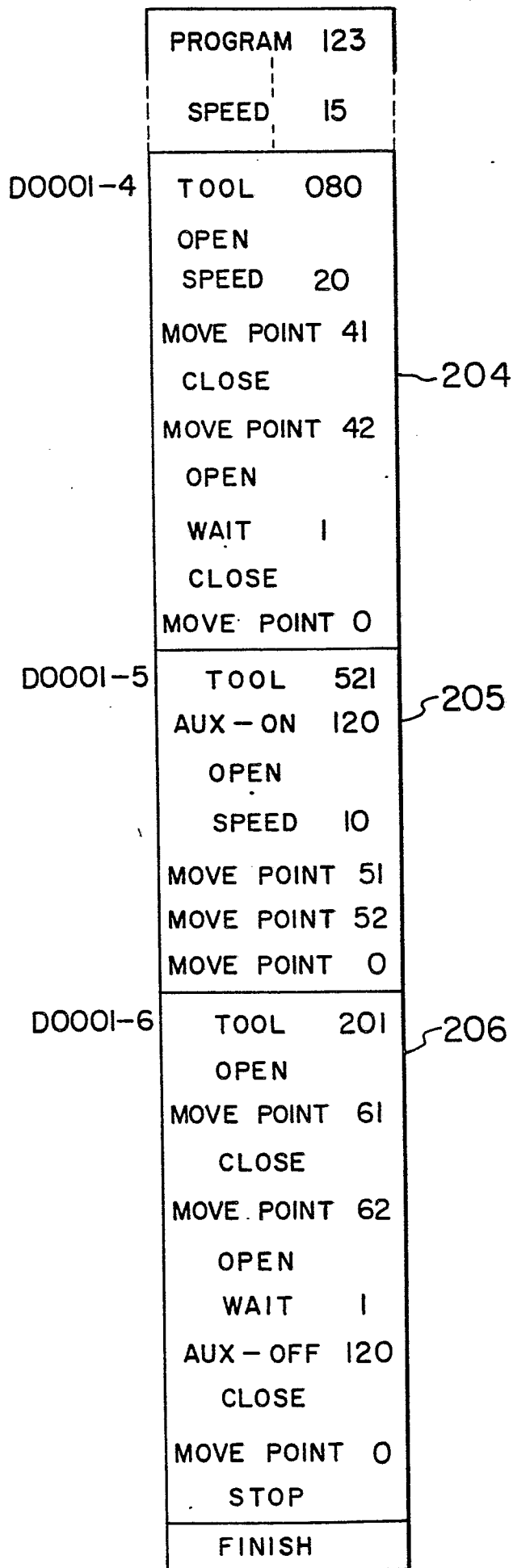


FIG. 12



10/11

FIG. 13



START CONDITION DATA
FOR D0001-4

SPEED	15	214
AUX-OFF	120	

END CONDITION DATA
FOR D0001-4

SPEED	20	224
AUX-OFF	120	

START CONDITION DATA
FOR D0001-5

SPEED	20	215
AUX-OFF	120	

END CONDITION DATA
FOR D0001-5

SPEED	10	225
AUX-ON	120	

START CONDITION DATA
FOR D0001-6

SPEED	10	216
AUX-ON	120	

END CONDITION DATA
FOR D0001-6

SPEED	10	226
AUX-OFF	120	

11/11

FIG. 14

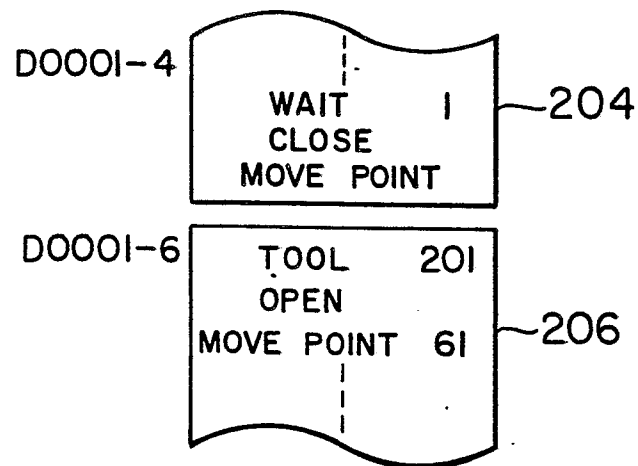


FIG. 15

